ENABLING EXPLORATION MISSIONS NOW: APPLICATIONS OF ON-ORBIT STAGING

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Abstract

Future NASA Exploration goals are difficult to meet using current launch vehicle implementations and techniques. We introduce a concept of On-Orbit Staging (OOS) using multiple launches into a Low Earth orbit (LEO) staging area to increase payload mass and reduce overall cost for exploration initiative missions. This concept is a forward-looking implementation of ideas put forth by Oberth and Von Braun to address the total mission design. Applying staging throughout the mission and utilizing technological advances in propulsion efficiency and architecture enable us to show that exploration goals can be met in the next decade. As part of this architecture, we assume the readiness of automated rendezvous, docking, and assembly technology.

Introduction

Our premise begins with a set of launch vehicles, which place fuel tanks into LEO in advance of spacecraft or human assets. From this vantage location we designed trajectories to the moon and Mars. We validated this concept with high fidelity analysis to assess feasibility, validate assumptions, and verify that requirements can be met. Using the On-Orbit Staging (OOS) concept, we found a quantum leap in payload mass; a 300% increase over current methods is common.

We analyzed the benefits or efficiency of using multiple launches into LEO where spacecraft and fuel tanks can be mated to form a larger vehicle versus direct transfers to either the moon or Mars. Results using current launch vehicle technology and propulsion systems are used as a point of comparison. The concept compares a direct orbit transfer of a single launch versus a departure from the LEO staging area. Trajectory data was generated using operational GSFC mission design simulation capabilities. This analysis looks at several launch vehicles including the Delta and Taurus classes. The analysis also addresses the use of high performance Liquid Oxygen / Hydrogen, bi-prop, and other more advanced propulsion systems. Launch Vehicle information and propulsion system characteristics are provided (see sample shown in Figure 1). Figure 2 presents a selected scenario and associated mass improvements.

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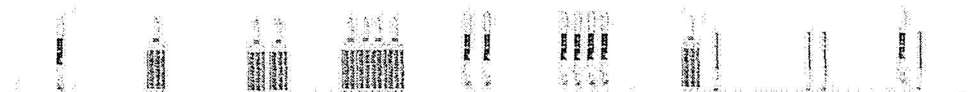
This concept enables missions unattainable by current launch techniques. It increases the current ratio of payload mass to launch mass, from which the savings can go into the instrument and payload, not necessarily the spacecraft bus or system engineering. It reduces design cost to build instruments under tight mass, power, and thermal budgets and leads to the elimination of the need to develop single-fault tolerant systems. It allows flexible program schedule and enables use of off-the-shelf parts. We can now use multiple launch vehicles to accomplish single large complex missions not previously feasible assuming robotic rendezvous, docking, and assembly capabilities exist.

Figure 1. Sample Mass increases for OOS.

Direct vs. On Orbit Staging

Potential Multiple Launch Vehicle Combinations
Payload Mass Capabilities in Metric Tons



Launch Vehicle(s)	Delta-II 2925 Direct	Delta-IV 4050H Direct	Delta-IV 4050H Staging	Delta-IV 4050H Staging	Delta-II 2925H Staging	Delta-II 2925H Staging	Delta-IV & Taurus Staging	Taurus 2110 Staging	Delta-II & Taurus Staging
Number of LVs	1	1	2	4	2	4	1 each	2	1 each
Payload Mass to Lunar Orbit	1	7	18	38	5	9	10	1	3
Payload Mass to Lunar Surface	0.6	4	13	26	3	6	7	0.7	2
Return Payload Mass to LEO from Moon	0.1	1	5	9	1	2	2	<0.1	0.3
Payload Mass to Earth-Moon Libration Orbit	1	8	20	40	5	10	10	1	3
Payload Mass to Mars Orbit	0.6	3	10	22	3	5	6	0.6	2
Payload Mass to Mars Surface	0.3	1	5	10	1	2	3	0.3	1
Return Payload Mass to LEO from Mars	[kgs]	0.1	1	3	0.1	0.3	.5	0	0.1

One Metric Ton = 1000 kg ~ 2204 lbs (a VW Beetle weights ~2800lbs)
Current payload to GEO, DII = 1Mt and D-IV = 8Mt
Most masses are rounded to nearest integer

Assumes LOX/H or Bi-prop propulsion systems with ISP = 465 sec or mixed 465/320
The Apollo LEM was approx. 6-8MT total mass with fuel

Figure 2. Mars Sample Return Scenario using OOS